SEASONING OF WHITE OAK FOR TIGHT COOPERAGE

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SEASONING OF WHITE OAK FOR TIGHT COOPERAGE

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SUMMARY

Losses in the tight cooperage industry, due to seasoning, can be reduced through improved seasoning practices, a survey of current practices disclosed. End checks, perhaps the greatest source of loss, can be materially reduced by the application of a suitable coating on the ends of stave and heading bolts immediately after they are cut from the log. Improved air- and kiln-drying practices will also reduce end checking. Properly established final moisture content specifications will reduce breakage losses during bending operations and also reduce leakage of liquids from the barrels during use. It was experimentally shown that green staves and heading can be successfully kiln dried for use in tight cooperage, in a properly designed and operated dry kiln, without preliminary air drying.

INTRODUCTION

Considerable quantities of high-quality white oak timber are converted each year into tight cooperage. Because of the high quality of the wood required, only a small percentage of an average white oak stand is suitable for this product. This, coupled with moderate to heavy losses during seasoning and fabrication, has resulted in the high cost of the finished product and excessive waste of raw material. Furthermore, seasoning defects, primarily end checks, in the finished barrels result in leakage of liquids from the barrels during storage and shipment. These losses of wood and liquids are causing

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the tight cooperage industry considerable concern. The Associated Cooperage Industries of America, Inc., requested the Forest Products Laboratory to investigate existing seasoning practices in the industry and recommend changes in these practices that would reduce losses due to improper seasoning.

Work was begun in Feburary 1948 and consisted broadly of two phases. In the first phase, plants were visited to get information on current practices. In the second phase, experiments were made to develop better drying methods.

Information was obtained on air- and kiln-drying procedures at cooperage operations in three areas, Louisville, Ky., St. Louis, Mo., and Russellville, Ark. In the Louisville and St. Louis areas, plant personnel was questioned relative to losses, dry kilns and drying procedures were inspected, dried staves and heading were examined before and after fabrication of the barrels, and moisture content data were obtained. In the Russellville area, the control of end checking was investigated by the use of (1) end coatings, and (2) protective measures other than end coatings, on bolts.

To find improved drying methods, oak staves were kiln dried at the Laboratory under various conditions of heat and humidity, and the dried staves were taken to a cooperage plant, inspected for suitability by plant personnel, and fabricated into barrels.

RESULTS OF PLANT SURVEYS

Information Obtained by Interviews

Plant employees from firm presidents to kiln operators were interviewed in an effort to get information as to where and how seasoning losses occur. Their answers indicated there is great diversity of opinion on this subject. The following statements, which are based on a summation of the answers to the questioning, illustrate this diversity, not to say disagreement. Opinion appeared to be about equally divided for and against each point of view:

1. Losses are not due to end checking in the bolts from which stave and heading stock is cut.

2. Most losses are due to end checking of staves and heading during air seasoning.

3. Most losses are due to end checking during kiln drying.

4. End checking and other seasoning defects are due to improper air- or kiln-drying procedures.

5. A considerable number of staves are lost because of worm damage.

6. Greatest losses occur during bending operations and are due to breakage of staves.

7. Staves cannot be kiln dried green from the saw, because the long exposure conditions removes all the "life" from the wood, which contributes to breakage during bending.

Among statements that received little support from most others interviewed were:

1. Staves air seasoned for more than 2 years become very brash, and breakage losses increase during fabrication.

2. Staves kiln dried green from the saw impart a bad taste to the liquid stored in barrels made from these staves. Therefore, staves should be thoroughly air dried before being kiln dried.

3. The steaming treatment given to prepare the staves for bending is too short.

It was the opinion of a majority of those interviewed that end checking could be materially reduced by cutting white oak logs into bolts and staves at the cooperage plants rather than at stave mills. Many emphasized that bolts should be cut into staves and heading as soon as possible.

Information on the amounts of loss due to seasoning defects and failures during fabrication was generally not available. Personnel at one plant, however, stated that losses due to seasoning defects, mostly end checks, ranged from 3 to 5 percent, based on the gross volume of rough-sawed staves and heading received at the plant. They were attributed entirely to air drying. On the basis of production figures, this amounted to a loss, due to seasoning defects, of from 27 to 45 barrels per day. The same plant also reported losses during fabrication of 0.5 to 1 percent due to shrinkage and to breakage during bending, which amounted to about 5 barrels per day.

Although this plant was kiln drying only well air-dried staves when visited, at other times green staves had been kiln dried with a seasoning loss of only 2 percent. The additional kiln time required to kiln dry the green staves, however, coupled with limited kiln capacity, caused this firm to fall behind production requirements, and as a result it was forced to air dry the staves before kiln drying them.

Employees at another plant stated that their total loss was about 20 percent of the gross volume of rough-sawed staves and heading received at the plant. Of this total, 6 to 7 percent was due to seasoning defects, mostly end checks, divided evenly between air and kiln drying; another 4 percent was due to shrinkage, and 10 percent was due to bending failures, worm holes, and natural defects. Based on daily production, the loss due to seasoning defects alone amounted to approximately 65 barrels per day.

End checks, regardless of when they occur, contribute to waste in the tight cooperage industry. End checks starting in the bolts may, under some conditions, penetrate deeply enough to appear in the staves even after they are equalized (end-trimmed). Also, when a bolt is sawed into staves on the barrel saw, entire cuts are occasionally thrown out as scrap without going through the equalizer, because they have severe end checks which will obviously not leave a stave of usable length after equalizing.

A brief investigation was made at Russellville, Ark., on the use of end coatings and other protective measures to control end checking. The purpose of the work was to determine the effectiveness of end coatings and other means of end protection in preventing end checking in stave bolts, and the best place in the sequence of operations for application of these coatings.

Effectiveness of Coatings on Bolts

End checking in bolts was controlled over a month's storage during severe spring drying weather with end coatings applied within a few hours after the bolts were cut from the tree. Partial, but sufficient, control was obtained with one coat of filled, hardened gloss oil, an end coating developed by the Forest Products Laboratory. Three proprietary coatings gave almost perfect protection. Figures 1 and 2 show the results of these end-coating treatments. All of the end checks in the bolts coated with filled hardened gloss oil (fig. 1) were slight and most of them were removed in equalizing the staves.

Filled, hardened gloss oil can be made by any varnish manufacturer according to a formula that is available at the Forest Products Laboratory. In warm weather this coating can be made more effective by evaporating some of the solvents. For cold weather use it can be thinned by adding a small amount of petroleum thinner or turpentine.

Time to Apply Coatings

The best time to apply coatings probably would be right after the bolts are sawed from the logs and split. If the bolts are to be carried to a road and ricked up within a few hours, it should be satisfactory to end coat them immediately after they are ricked.

Some bolts that had been stored at least a month were included in the test. These already contained end checks ranging from 0.2 to 1.0 inch deep. Application of end coatings on these bolts did not prevent the deepening of the checks. The result was that moderate to severe end checks were still present in some of the staves cut from the bolts after equalizing.

Effectiveness of Other Protective Measures

Other measures tested to see if they would control end checking were:

1. Standing the bolts upright on the ground with upper ends end coated.

2. Standing the bolts upright on the ground with upper ends shaded.

3. Allowing the bolts to lie flat on the ground.

The lower ends of the bolts standing upright on the ground showed a small amount of shallow end checking. Only about 10 percent of the staves cut from these bolts showed end checks on the protected end after being equalized. This type of protection, if the upper end was end coated, appears to be helpful if the storage period does not exceed 1 month.

Shading of the upper ends of the bolts by limbs and leaves (fig. 3) gave only slight protection. About 50 percent of the staves cut from these bolts showed end checks after being equalized.

The bolts stored flat on the ground (fig. 4) were severely end checked. Almost every stave cut from these bolts was found to be end checked after being equalized.

End Checking of Staves During Air Seasoning

The staves cut from the bolts used in the end coating study were air dried 77 days during May, June, and July. They were crib piled for air drying. All end coatings were removed from the bolts by end trimming before the staves were cut.

Practically all of the staves end checked during air drying. The checks probably developed very early in the seasoning process, for similar staves piled for air drying in April end checked within 2 days. Figure 5 is a closeup view of end-checked staves that were cut from end-coated bolts and end trimmed before air drying. The diagonal end checks and the checks parallel to the annual rings are types that might lead to leakage if they penetrate to the croze.

Most of the checks were between 1/4 and 1/2 inch deep. A few, however, penetrated farther. By trimming 1/2 inch off each end of the air-dried staves most of these checks were removed.

End checking after air drying.--The cores of the air-dried staves were wet enough to end check when the ends were trimmed back about 1/2 inch and exposed to the sun and air for 6 hours. The new checks penetrated 1/4 inch on the average, with some penetrating as much as 0.6 inch.

Normally, staves are not equalized until after they are kiln dried, so this was a severe exposure test. It does illustrate, however, that air-seasoned staves are still susceptible to end checking if they are equlized before being kiln dried.

Moisture content of air-dried staves.—The average moisture content of the staves after 77 days of air drying was 18.4 percent, on the basis of the weight of the oven-dry wood. Moisture meter readings taken on individual staves in three different crib piles, each containing 100 staves, indicated that the staves in the three lower courses in the crib had a moisture content about 1 percent higher than the rest of the staves.

Oven-dry moisture distribution tests in the air-dried staves showed that the shells averaged 15.2 percent and the cores 20.3 percent in moisture content.

Drying Procedures at Cooperage Plants

Air-drying and kiln-drying practices at cooperage plants were observed. At least one plant representative was present at all times. Practices that appeared faulty were called to his attention and an attempt was made to find out why they were used.

Storage of Bolts at Cooperage Plants

Stave and heading bolts are not commonly stored at cooperage plants. When they are, the storage period is usually short. Whether the storage time is long or short, however, considerable damage may result from end checking if the bolts are improperly protected.

Quartered stave bolts in outside storage piles are shown in figure 6. The bolts were piled in late November and the picture was taken the following February after a storage period of approximately 2-1/2 months. During this period, particularly during the latter part of November, they had been exposed to rather severe air-drying conditions. The ends of these bolts were severely checked, some checks extending to a depth of at least 2 inches.

Bolts piled outside at another plant in late January had by April of the same year, sustained end checking, which while severe, was not so deep as that shown in figure 6, maximum penetration being about 1 inch. This is accounted for by the fact that they were exposed to less severe air-drying conditions, the relative humidity being fairly high during the storage period.

The presence of end checks in the bolts may not be so serious as it appears, because the staves are equalized after being kiln dried. This equalizing operation usually removes about 1-1/2 inches from each end of the stave, thus eliminating a large percentage of end checks. At some plants, however, the equalizing operation does not trim an equal amount from each end of the stave, in which case deep end checks may still be present in one end. Obviously, end checks should be prevented if at all practical.

Air-drying Practices at Cooperage Plants

Staves and heading are piled for air seasoning in several ways. Since only a few plants were visited, it is unlikely that all the piling methods used by the industry were seen.

There appear, however, to be two general methods in use; (1) open piling for fast drying, and (2) close piling for slow drying. The first method is used in late fall, winter, and early spring, at which times drying conditions are fairly mild. The second method is used during periods of severe drying conditions and on stock stored for extended periods outside.

Close piling of staves for slow drying or extended storage is shown in figure 7. The staves are edge lapped as shown, so that they will not flatten under weight. They are self-stickered, the staves being used as stickers. In some instances, the stave stickers project an inch or two beyond the ends of the staves. This projection serves as a sunshield and as added protection from rain and snow. Although not shown, the foundations are quite low. This is not considered good practice, particularly if the yard does not have good drainage.

Close piling of heading is shown in figure 8. This is commonly called end-lapped piling. This method is used for slow drying or for prolonged outdoor storage. As shown, 1- by 1-1/2-inch stickers are placed at each end in every course. At some plants, however, heading is used for stickers.

Another method of piling staves for slow drying, or prolonged outside storage, is shown in figure 9. This is called edge piling. It will be noted that staves are piled solid at the top of the pile, a procedure that retards air movement through the pile tremendously, thus prolonging the drying time. Also, because many staves are in direct contact with each other, the way is paved for the spread of stain and decay. In fact, decay was found near the tops of the piles shown in figure 9. Again low foundations are in evidence, some being so low that the staves actually contact the ground.

Figure 10 shows staves package piled for air seasoning. The method of piling used is the same as that illustrated in figure 7. This method is satisfactory if fork-lift or straddle trucks are used to handle the material. Heading can also be package piled by using the method of piling shown in figure 8.

Open piling or crib piling of staves and heading is illustrated in figures 11 and 12. This method of piling is used to secure fast drying during periods of mild drying weather. Under rather severe drying conditions, however, end checking may become severe. Furthermore, the end checks may extend to a considerable depth, subsequently causing leakage at the croze in the barrel.

The foundations of the crib piles are very low. In fact, some of the lower staves and heading in the piles (figs. 11 and 12) were in contact with the ground. If yard drainage is poor, the lower portions of the piles may be covered with water, especially during rainy periods or when the snow is melting. This will open and deepen old checks. It also paves the way for stain and decay.

Moisture content of air-dried staves and heading just before kiln drying.--Moisture content data on air-dried staves and heading were obtained at four plants just before the material was kiln dried. Moisture determinations were made by the oven-drying method and with an electric moisture meter.

The data showed that the moisture content of the air-dried staves and that of the heading stock were about the same. Therefore, the data obtained were combined in the summary shown in table 1.

Kiln Drying at Cooperage Plants

The kiln-drying equipment and kiln-drying procedures at the plants visited varied considerably. There was also a wide range in the final moisture content of the kiln-dried stock, a condition that might cause some trouble during fabrication and subsequent use.

The dry-kiln equipment in use at the plants visited ranged from the typical old hot box to modern forced-circulation kilns of both the progressive and compartment types. Since the proper kiln drying of white oak tight cooperage stock is very important, from the standpoint of drying defects and moisture content, close control of drying conditions is required. Therefore, good dry kilns of the compartment type, with automatic control of drying conditions, should be best suited.

Stacking of staves and heading for kiln drying was, in general, much the same at all the plants visited. Heading stacked for kiln drying is shown in figures 13, 14, and 15. End lapping was used in all cases. There are, however, differences that will affect drying time and uniformity of moisture content. The truckload of heading shown in figure 13 has 1- by 1-1/2-inch stickers between courses at each end of the load. In figure 15, however, the heading was self-stickered; that is, heading was used as stickers at the ends of the loads. The heading used as stickers, as well as the heading these pieces contact, dries very slowly as compared to the stock that has both faces exposed to circulating air. This results in nonuniformly dried stock. Moisture content data obtained showed that, when the stock with exposed surfaces had reached a moisture content of 8 to 10 percent, the heading used as stickers and the stock contacting these was at a moisture content ranging from 14 to as high as 22 percent. This variation in moisture content will very probably lead to serious trouble because the fabricated heads will shrink in storage and use.

Another variation in stacking is shown in figures 14 and 15. In figure 14 the end laps are not too great, ranging from 1 to 3 inches. In figure 15, however, end lapping was found to be about twice as great. The longitudinal moisture gradient was fairly uniform in the heading with the short end laps, but varied considerably where the pieces lapped one another to a greater extent varying from 8 to 23 percent after kiln drying. This longitudinal moisture gradient can also cause serious trouble in the fabricated heads, the ends of the heading shrinking more than the centers and thereby opening up the joints in the finished heads.

Staves stacked for kiln drying are shown in figures 15 to 18, inclusive. The edge-lapping method (figs. 15 and 17) and the edge-piling method (fig. 18) of stacking are generally used. The edge-lapping method will result in faster and more uniform drying than the edge-piling method, because more drying surface is exposed to the circulating air. The type of dry kiln used, however, may necessitate slight modifications in the general method of stacking.

Figures 16 and 17 show staves stacked for kiln drying in internal-fan, cross-circulation kilns. The air movement in both cases is parallel to the staves used as stickers between courses. The circulating air contacts most of the drying surfaces, and drying is quite uniform.

Figure 18 shows staves stacked for kiln drying in a natural-circulation kiln. Vertical flues are provided for vertical air movement, a definite requirement for kilns of this type. It will be noted, however, that the two top courses of staves cover the vertical flues. In a natural-circulation kiln most of the circulating air moves vertically within the load, from the top downward during the early stages of drying, but possibly upward during final drying. Covering the flues at the top of the load retards vertical air movement considerably, extending the drying time and producing nonuniformly dried stock. Therefore, the flue tops should not be covered.

Another truck load of staves stacked for drying in a natural-circulation kiln is shown in figure 19. There are several things wrong with the stacking of this load. The vertical flues are too narrow, are spaced too far apart, and are not continuous from bottom to top of the load, thereby restricting air circulation. Staves are solid piled at the top of the load in the belief that kiln capacity is increased. Air cannot circulate around these staves. Also, when the truck is moved into the kiln the solid-piled staves topping the load slide downward when jarred, close the vertical flues, and stop vertical air circulation. The supposed gain in kiln-holding capacity was more than nullified by the increased drying time resulting from restricted air circulation. Furthermore, the variation in the final moisture content was great, particularly in the solid-piled staves at the top of the load. The minimum and maximum moisture content of kiln-dried staves going into production at this plant was 5 and 18 percent, respectively.

Kiln-drying procedures at cooperage plants varied tremendously between plants. Generally, the stock was thoroughly air dried prior to kiln drying. Occasionally, however, it was necessary to kiln dry green or partially air-dried stock.

Two of the plants visited did not use kiln samples. Moisture content of the charge was checked from time to time by oven-drying determinations or moisture meter readings taken on a limited number of staves or heading selected at random from the kiln charge. Usually, these moisture checks were made from the loads adjacent to the kiln doors. The variation in final moisture content of the staves making up the kiln charge reflected this rather loose method of moisture testing.

Plants using kiln samples obtained more uniform drying. The samples, however, were not selected carefully at all times. Furthermore, they were not always located where they represented the drying of the kiln charge as a whole; as a result, the moisture content of the stock going into production often varied considerably.

Very little specific information was available on the drying schedules used. One plant having forced-circulation kilns was using the dry-bulb temperatures recommended in hardwood schedule No. 7 of Forest Products Laboratory Technical Note No. 175. The relative humidities used, however, were 10 percent lower than those given in schedule 7.

Another plant used an extremely mild schedule. The initial drying conditions on thoroughly air-dried staves and heading were 100° F. dry bulb and 99° F. wet bulb, practically saturated conditions, for 3 to 4 days. The conditions were then changed to 110° F. dry bulb and 100° F. wet bulb for another 3 or 4 days. The final conditions were 120° F. dry bulb and 100° F. wet bulb, much too mild to obtain a satisfactory drying rate.

Although no green stock was being dried at the time the visits were made, it was reported that the drying time on green staves varied from 30 to 50 days and on green heading from 35 to 55 days. The drying time on thoroughly air-dried staves varied from 8 to 21 days and on air-dried heading from 12 to 32 days. The longest drying time reported (32 days) was by the plant using the extremely mild schedule in a modern forced-circulation kiln. No kiln samples were used at this plant.

Drying defects were confined mostly to end checks. The amount of honeycomb detected was so small that it can be neglected. This is probably due to the low temperatures used in the early stages of drying.

Observations made on air-dried staves and heading before and after kiln drying indicated that most, if not all, of the end checking occurred during air drying. In one plant, however, end checks that developed during air drying were extended in kiln drying by the use of extremely high relative humidities in the initial stages of drying that caused end swelling.

Moisture Content of Kiln-dried Stock

Neither the Wooden Barrel Manual nor the Grade Rules and Specifications for Tight Barrel Staves and Heading, both published by The Associated Cooperage Industries of America, Inc., specify the final moisture content to which staves and heading should be kiln dried before going into production.

It is the general feeling in the cooperage industry that leakage is held to a minimum when staves and heading for tight barrels are kiln dried to a moisture content of 8 to 10 percent. Experience has shown, however, that breakage of staves during the bending operation becomes excessive if the staves are dried to these low values. A moisture content of 18 to 20 percent in the staves holds breakage to a minimum, but subsequent shrinkage during storage and use results in excessive leakage. A moisture content of 12 to 14 percent in the staves, however, appears to hold combined losses due to shrinkage and breakage to a minimum. Therefore, the plants in general are attempting to dry the staves to this value. Shrinkage appears to be causing most of the trouble in the heads. Therefore, the desired final moisture content for heading is generally considered to be 8 to 10 percent.

Moisture content data obtained at four plants on staves and heading going into production are shown in tables 2 and 3. These were obtained by both the oven-drying method and electric moisture meters. The number of tests made was small. It is believed, however, that they give a fairly true picture of the final moisture content. The data shown in these tables indicate that the desired moisture standards were not attained. Trouble may occur in using this stock. The extremely low moisture content in the staves might result

in greater breakage during bending and the higher values in both staves and heading will bring increased losses through leakage due to shrinkage.

RESULTS OF EXPERIMENTAL WORK

Kiln Drying of Green White Oak Staves

The general feeling in the cooperage industry is that green white oak staves cannot be kiln dried without excessive losses caused by end checks and honeycomb. It is also felt that the "life" is taken out of the wood during the long time in the kiln, and that breakage is increased thereby during the bending operation. It has been the opinion of men familiar with the seasoning of wood, however, that green oak can be satisfactorily kiln dried for this use. Therefore, it was decided to kiln dry a small number of staves in the Laboratory's experimental kilns, which are of the forced-circulation type.

Five groups of green staves, each group containing enough staves for one barrel and five kiln samples, were obtained from a cooperage plant and kiln dried under different drying schedules. The kiln-dried staves were shipped to the cooperating plant and were followed through the fabrication procedure by a plant and a Laboratory representative. The finished barrels were carefully examined.

Initial Moisture Content

Some drying had taken place before the staves arrived at the Laboratory. There was also a small amount of end checking present in all the staves.

The initial moisture content of the five samples in each group, determined by the oven-drying method, was as follows:

Group A: average, 51.1 percent; minimum, 40.7 percent; maximum, 58.6 percent.
Group B: average, 51.2 percent; minimum, 46.5 percent; maximum, 55.9 percent.
Group C: average, 48.1 percent; minimum, 41.3 percent; maximum, 54.7 percent.
Group D: average, 48.5 percent; minimum, 40.8 percent; maximum, 54.9 percent.
Group E: average, 42.5 percent; minimum, 40.4 percent; maximum, 45.4 percent.

Drying Schedules Used

Each group was dried under a different drying schedule, varying from a mild to a rather severe initial drying condition. Groups A to D, inclusive, were exploratory runs. From the data obtained, a modified schedule was developed and used on Group E. This was aimed at securing quality as well as faster drying.

Seasoning Defects

As previously stated, all the staves in each group contained small end checks prior to kiln drying. More end checks developed during the initial stages of kiln drying but they began to close in all groups at moisture content values varying from 30 to 40 percent. All end checks were closed at an average moisture content of 20 percent.

Data obtained on the depth of penetration of these checks in the five kiln samples of each group were as follows:

Group A (mild schedule).--Penetration of end checks varied from 3/8 to 7/8 inch. Average penetration was 9/16 inch. One stave had a natural defect on one end which increased average end checking and depth of penetration.

Group B (moderate schedule).--Penetration of end checks varied from 1/8 to 5/8 inch. Average penetration was 5/16 inch. No natural defects were present in the sample staves.

Group C (moderately severe schedule).--End-check penetration varied from 1/8 to 2 inches. Average penetration was 1-1/8 inches. Deepest penetration, 2 inches, was in a sample stave that had a natural defect on one end.

Group D (severe schedule).--Depth of end check varied from 1/8 to 3 inches. The average penetration was 1 inch. Deepest penetration, 3 inches, occurred in a sample stave that had a natural defect near one end.

Group E (modified schedule).--End-check penetration varied from 1/8 to 1-3/4 inches. Average penetration was 13/16 inch. Two sample staves in this group had natural defects near the ends that increased end-check penetration.

Final Moisture Content and Drying Time

Each group of staves was given a 1-day equalization treatment in the final stage of drying. The equilibrium moisture content condition used for this treatment was 12 percent at a temperature of 160° F.

The final moisture content data and the total drying time for each group are shown in table 4.

In initial average moisture content, Group E was about 9 percent lower than Groups A and B. For this reason the drying time of 13 days obtained with Group E cannot be used in a direct comparison of total drying time between groups. On the basis of moisture loss data obtained during drying, however, it is believed that Group E could have been dried from an average initial moisture content equivalent to that of Groups A and B, in 15 or 16 days.

Plant Processing of Experimental Staves

Each stave was followed through the plant from the start to the finish of the fabrication procedure. The information obtained after the equalizing and jointing operations is summarized in table 5. All of the staves in all five groups were end checked, but only one stave was rejected for this reason. Others were rejected after equalizing and jointing because of natural defects and insufficient width. One stave broke in the bending process, but the breakage was attributed to severe cross grain. The influence of kiln schedules on bending strength was not detected.

It was the opinion of plant personnel that the staves which were kiln dried without preliminary air drying came through the fabrication procedure with no more losses or rejection of material than normally occurs with staves air dried prior to kiln drying. The finished barrels were accepted and shipped with the others being made from air-dried and kiln-dried stock. Had this study been made on a larger scale, it would have been desirable to obtain performance data on the barrels.

Recommendations for Kiln Drying Green Staves and Heading

The amount of material that was used in experimental kiln drying of green staves was not sufficient to warrant a general recommendation for kiln drying green staves for tight barrel manufacture. Experience with the kiln drying of oak and other woods, however, for uses requiring maintenance of inherent strength provides, coupled with these data, a basis for a proposed kiln-drying schedule that should prove satisfactory. Green stock should be kiln dried in a forced-circulation kiln, with the stock piled to take full advantage of the circulation provided, and the kiln should be equipped with instruments so that good control of temperature and relative humidity is always obtained.

The following schedule is designed to keep end checking to a minimum, and the low-temperature operation should not significantly reduce bending strength:

Kiln-drying schedule for green white oak staves and heading* for tight cooperage

Step number	Moisture content	Dry-bulb temperature	Wet-bulb temperature	Relative humidity	Equilibrium moisture content
	Percent	° F.	° F.	Percent	Percent
1	Above 40	110	105	84	16.2
2	40-30	115	108	79	14.1
3	30-20	120	100	49	7.9
4	20-final	160	120	31	4.3

*Staves and heading air dried to a moisture content of below 30 percent can be subjected to Step 3 drying conditions when placed in the kiln.

SUMMARY

Information obtained in the inspection of seasoning practices and studies of end coating and kiln drying is summarized as follows:

1. Opinions among men in the industry differed greatly as to the major causes of losses due to seasoning defects and stave breakage. There were also differences of opinion regarding this matter between personnel at the same plant.

2. Air- and kiln-drying practices varied considerably. Data obtained indicated a wide range in the final moisture content both in heading and staves. Some dry kilns were not capable of doing a good job of drying, and some good dry kilns were improperly operated.

3. Staves and heading are not kiln dried to a specific moisture content standard.

4. End checking in seasoning and the breaking of staves during bending are the greatest causes of losses.

5. End coating of bolts immediately after they are cut from the logs will reduce end-checking losses.

6. Most of the end checking occurred during air drying. These end checks were in some cases extended by high humidity treatments in subsequent kiln drying.

7. Green staves can be kiln dried in a good compartment kiln without increasing losses due to end checking and to breakage during bending.

Suggestions for Reducing Losses

Seasoning defects cannot be corrected by modern fabricating machines. This correction must be made through improved air- and kiln-drying practices. Practices suitable for use at one plant may not fit into the set-up of another plant. Tight cooperage stock must, however, be carefully dried if losses are to be kept to a minimum. Initial drying conditions influence end-checking losses, and excessive kiln temperatures affect bending strength.

Suggestions that should reduce losses due to seasoning and to breakage during bending are as follows:

1. End coat the bolts immediately after they are cut from the log with a coating that will stand up under kiln temperatures. This coating should remain on the staves and heading until they have been kiln dried.

2. Pile the staves and heading for air drying in a manner that will promote fast drying with a minimum amount of end checking.

a. During mild drying weather crib-piling the stock as shown in figures 11 and 12 is satisfactory.
b. During severe drying weather pile the stock for slower drying. The methods of piling shown in figures 7 and 8 should yield good results.

3. Covering the tops of the piles of staves and heading with some type of roof is desirable. A 4-inch space between the top course of stock and the roof should be provided for good air circulation.

4. Use higher pile foundations to secure faster drying near the bottom of the pile. A foundation height of 12 inches would be desirable.

5. Stack the stock for kiln drying to best suit the kiln available. The methods of stacking shown in figures 13, 14, 16, and 17 should give good results. For a natural-circulation kiln the loads should be stacked with flues for better movement of air through the stock. These flues should not be closed at the top. Do not end lap heading more than 1-1/2 inches.

6. Select kiln samples representative of the stock being dried, prepare these in accordance with standard procedures, and place them in the kiln loads so that their drying represents the drying of the whole kiln charge. The number of samples required will depend upon the size of the kiln charge and the variation in the initial moisture content of the stock being dried.

7. Compartment-type forced-circulation dry kilns that have automatic control of drying conditions are more efficient than progressive dry kilns. Increased production and closer adherence to improved moisture standards can be obtained in modern kilns of this design.

8. Do not subject air-dried staves to high humidity conditions at the start of or during kiln drying. Such conditions may cause end checks that are already present to penetrate deeper.

9. Establish a moisture content standard for staves and heading and kiln dry to this standard. A final moisture content of 8 to 10 percent for heading and of 12 to 14 percent for staves should hold breakage and leakage to a minimum.

Table 1.--Comparison of moisture content values in air-dried staves and heading at four cooperage plants

Plant number	Moisture tests	Moisture content		
		Average	Low	High
	Number	Percent	Percent	Percent
1	100	18.1	12.0	27.9
2	100	21.4	16.1	32.6
3	40	19.6	17.6	24.5
4	60	24.0	16.0	45.0

Table 2.--Moisture content of kiln-dried staves just before assembling into barrels

Plant number	Moisture tests	Moisture content		
		Average	Low	High
	Number	Percent	Percent	Percent
1	95	10.9	5.0	17.9
2	95	8.6	3.2	15.0
3	35	8.8	6.3	11.9
4	60	7.0	4.5	9.0

Table 3.--Moisture content of kiln-dried heading just before assembly into barrels

Plant number	Moisture tests	Moisture content		
		Average	Low	High
	Number	Percent	Percent	Percent
1	95	9.1	4.7	13.9
2	95	14.7	4.2	21.3
3	35	8.3	5.2	11.7
4	60	7.1	4.6	8.0

Table 4.--Final moisture content and total drying time for five groups of white oak barrel staves experimentally kiln dried

Group number	Final moisture content[1]		Drying time[2]
	Variations	Average	
	Percent	Percent	Days
A	12.7 - 15.8	13.8	23
B	12.5 - 15.6	14.0	23
C	12.9 - 15.1	14.0	17
D	12.3 - 14.9	14.0	17
E	13.1 - 15.1	14.1	13

[1]Data obtained from five kiln samples in each group.

[2]Includes 1 day of equalizing at end of run.

Table 5.--Information obtained on kiln-dried staves at cooperating plant after equalizing and jointing

Group number[1]	Staves showing end checks after equalizing (end trimming)	Staves rejected	Reasons for rejection
	Number	Number	
A	5	3	Would not joint smooth - 2 staves Edge check due to natural defect - 1 stave
B	2	2	Would not joint smooth - 2 staves
C	None	3	Jointed too narrow - 3 staves
D	2	3	Severe end check - 1 stave Would not joint smooth - 1 stave Edge check due to natural defect - 1 stave
E	None	3	Natural defects - 2 staves Jointed too narrow - 1 stave

[1]Each group contained 25 staves.

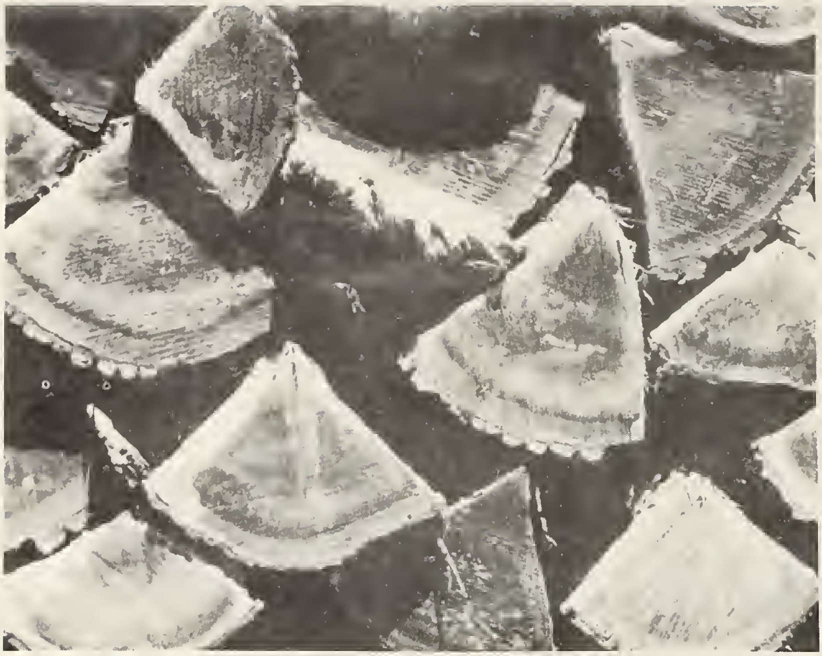

Figure 1.--White oak cooperage bolts coated with filled, hardened gloss oil, after 1 month of storage.

Figure 2.--White oak cooperage bolts coated with proprietary coatings photographed after 1 month of storage.

Z M 85998 F

Figure 3.--Checks in top ends of bolts that were stood on ground and shaded during 1 month of storage.

Figure 4.--Checks in bolts stored flat on ground, unprotected, for 1 month.

Z M 85999 F

Figure 5.--Close-up of end checking in staves from end-coated bolts, after air seasoning.

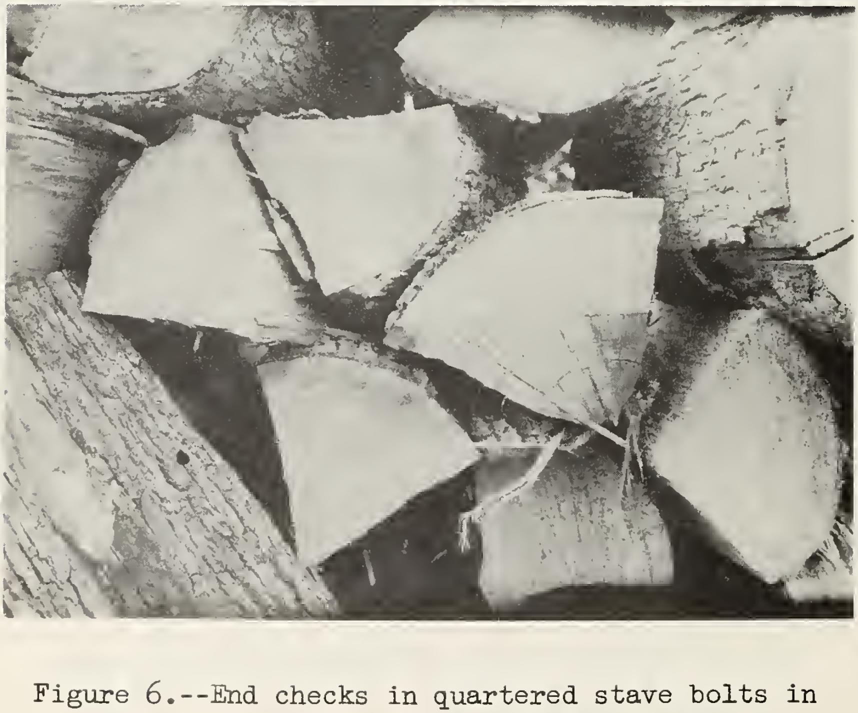

Figure 6.--End checks in quartered stave bolts in outside storage pile at a cooperage plant.

Z M 86000 F

Figure 7.--End and side view of pile showing "lap-piling" of staves for air drying or outside storage.

Z M 98533 F

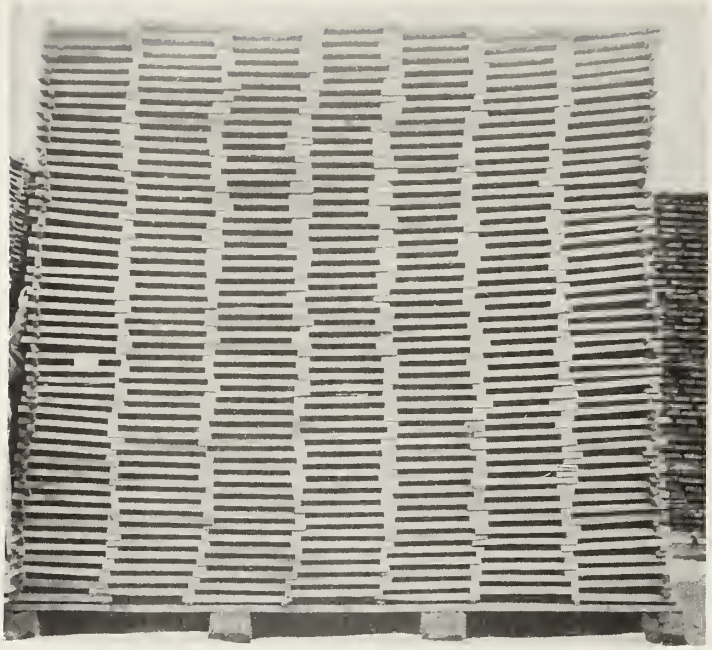

Figure 8.--End-lapped pile of heading. Above, side of pile showing method of lapping ends of stock. Below, front view showing close piling and central flue. Stickers used at ends of pile only.

Z M 86001 F

Figure 9.--Side view of pile showing edge piling of staves for air drying. Decay was found near the tops of these piles.

Z M 98536 F

Figure 10.--Package piling of staves for air drying. Upper, lift truck moving package. Lower, packages stacked for air drying.

Z M 86002 F

Figure 11.--Crib piling of staves for rapid air drying.

Figure 12.--Crib piling of heading for rapid air drying.
Z M 86003 F

Figure 13.--End view of a kiln-truck load of heading stacked for drying in a natural-circulation, end-piled kiln. Note vertical flue.

Figure 14.--Side view of a truckload of heading stacked for drying in an end-piled, forced-circulation kiln.

Z M 86004 F

Figure 15.--Heading stacked on kiln trucks for drying in an end-piled forced-circulation kiln.

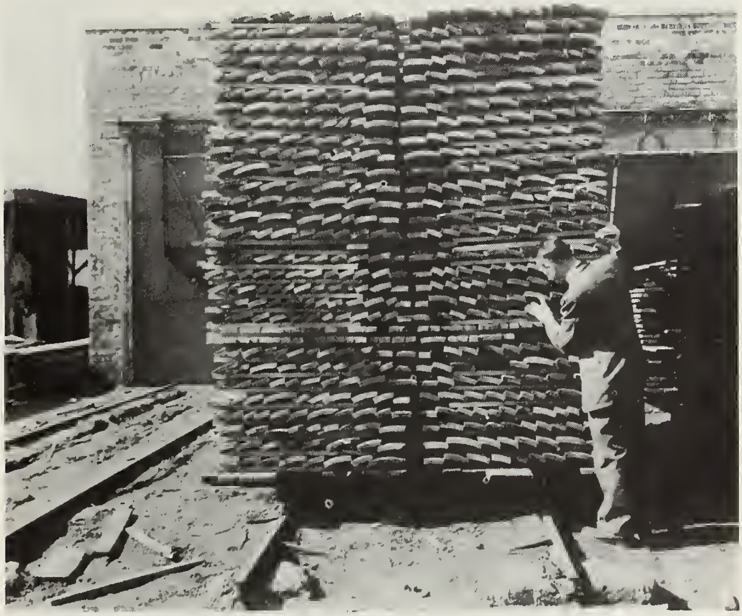

Figure 16.--End view of a kiln-truck load of staves piled for an end-piled, forced-circulation kiln.

Z M 86005 F

Figure 17.--Kiln-truck load of staves stacked for a cross-circulation kiln.

Figure 18.--View of a kiln truck load of staves stacked for a natural-circulation kiln. Note topping of load and vertical flues.

Z M 86006 F

Figure 19.--View of a kiln truck load of staves stacked for a natural-circulation kiln. Note method of topping load and small vertical flues.

Z M 98547 F